[0064] The above fiber position sensor 600 can be used in various position sensing applications as the transverse fiber interferometer shown in FIG. 1.

[0065] A number of embodiments have been described. Nevertheless, it will be understood that various modifications and enhancements may be made without departing from the spirit and scope of the following claims.

Claims

[c1] 1. A device, comprising an optical fiber having a first distal end and a second distal end, said second distal end having an end facet that is at least partially reflective and forms an angle with respect to a fiber core of said fiber to reflect an optical beam in a direction substantially perpendicular to said fiber core into or out of said fiber core through a side fiber surface at said second distal end opposing said end facet with respect to said fiber core, wherein said end facet has a non-flat profile to modify a propagation property of a beam reflected by said end facet.

[c2] 2. The device as in claim 1, further comprising:
a laser optically coupled to said first distal end to produce a probe laser beam into said fiber which is directed by said end facet at said second distal end to illuminate a surface that is at least partially reflective; and
a photodetector optically coupled to said first distal end to receive a reflected probe from said second distal end which is coupled to said fiber core by said end facet from the surface.

[c3] 3. The fiber device as in claim 2, further comprising an electronic circuit coupled to receive an output from said photodetector to detect a change in spacing between said side fiber surface and the surface along a direction substantially perpendicular to said fiber core from an intensity variation in said reflected probe beam.

[c4] 4. The device as in claim 1, wherein said end facet is curved.

[c5] 5. A device, comprising:

a laser to produce a probe laser beam;

an optical fiber having a first distal end optically coupled to receive said probe laser beam and a second distal end having an end facet that is at least partially reflective and forms an angle of about 45 degrees with respect to a fiber core of said fiber to reflect an optical beam in a direction substantially perpendicular to said fiber core into or out of said fiber core through a side fiber surface at said second distal end opposing said end facet with respect to said fiber core;

a measurand surface adjacent to said second distal end of said fiber and parallel to said fiber core, said measurand surface being in a plane that intercepts with another plane defined by said end facet to form a line substantially perpendicular to said fiber core, wherein said measurand surface is at least partially reflective to form an optical interferometer with said side fiber surface so that a first reflection of a beam produced at said side fiber surface interferes at said side fiber surface with a second reflection of the beam produced at said measurand surface; and

a photodetector coupled to receive a reflected probe beam through said fiber and representing the interference between said first and second reflections to produce a detector output indicative of a spacing between said measurand surface and said side fiber surface.

[c6] 6. The device as in claim 5, wherein said end facet is not flat.

[c7] 7. The device as in claim 5, where said fiber distal end facet includes multiple-planes for light reflection.

[c8] 8. The device as in claim 5, where said fiber distal end facet is polished and includes at least one curved surface for light reflection.

[c9] 9. The device as in claim 5, where said fiber distal end facet is coated with one or more layers of one or more light-reflecting materials.

[c10] 10. The device as in claim 5, wherein a fiber coupler to coupled light from said fiber to said laser and said photodetector.

[c11] 11. The device as in claim 10, further comprising at least another fiber coupler coupled to receive light from said laser and send an interferometric signal to said photodetector.

[c12] 12. The device as in claim 5, wherein a spacing between said side fiber surface and said measurand surface is selected so that a rate of a change in an intensity of said reflected probe beam with respect to a change in said spacing is at or near a maximum.

[c13] 13. The device as in claim 5, further comprising:
a substrate to which said fiber is engaged; and
a mechanical oscillator engaged to said substrate and having a sensing tip that changes its position with respect to said substrate when under an action of a force, said sensing tip having a reflective surface and positioned near said second distal end of said fiber,
wherein said measurand surface is a portion of said reflective surface on said sensing tip.

[c14] 14. The device as in claim 12, wherein said mechanical oscillator is a cantilever.

[c15] 15. The device as in claim 5, further comprising:

said fiber engaged to said substrate, where said fiber is made to form a mechanical oscillator, having a sensing tip that changes its position with respect to said substrate when under an action of a force, said substrate having a reflective surface and positioned near said second distal end of said fiber,

wherein said measurand surface is a portion of said reflective surface on said substrate.

[c16] 16. The device as in claim 5, further comprising first and second static magnets spaced from each other to form a gap therebetween, wherein said second distal end of said fiber and said measurand surface are located in said gap so that said measurand surface is substantially perpendicular to a static magnetic field produced by said first and second static magnets.

[c17] 17. The device as in claim 16, further comprising a movable magnet located in said gap, said movable magnet having a surface, a portion of which constitutes said measurand surface.

[c18] 18. The device as in claim 5, further comprising a semiconductor substrate and at least one micro-electromechanical system (MEMS) device formed on said substrate, said MEMS device has a movable reflective surface with a portion that constitutes said measurand surface, wherein said fiber is fixed relative to said substrate to measure a displacement of said movable reflective surface.

[c19] 19. The device as in claim 5, further comprising a semiconductor wafer processing chamber and a semiconductor wafer in said processing chamber, wherein said fiber is fixed relative to said wafer with said fiber core substantially parallel to said wafer.

[c20] 20. The device as in claim 5, further comprising a positioning element to control a position of said second distal end relative to said measurand surface.

[c21] 21. The device as in claim 20, wherein said positioning element modulates said position of said second distal end according to a periodic signal.

[c22] 22. A method, comprising:

guiding a light beam to a distal end of a fiber;

reflecting the light beam out of the fiber by an end facet which forms an angle with respect to the fiber core so that the reflected beam is substantially perpendicular to the fiber core;

directing the reflected beam to a reflective surface to which the fiber is substantially parallel;

collecting and directing a reflection from the reflective surface into the fiber; and

detecting the reflection to determine information regarding a spacing between the reflective surface and the distal end of the fiber.

[c23] 23. The method as in claim 22, further comprising modulating a position of the distal end of the fiber relative to the reflective surface.

[c24] 24. The method as in claim 22, wherein the reflective surface is a surface of a film over a semiconductor substrate, and further comprising:

using the reflection to measure growth of said film during a fabrication process.

[c25] 25. The method as in claim 22, wherein the reflective surface is a surface of a film over a semiconductor substrate, and further comprising:

using the reflection to measure etching of said film during a fabrication process.

[c26] 26. The method as in claim 22, wherein the reflective surface is a surface of a bulk material, and further comprising:

using the reflection to measure etching of the film during a fabrication process.

[c27] 27. The method as in claim 22, wherein said light beam is composed of one or more laser beams.

[c28] 28. The method as in claim 22, wherein the reflective surface is a moving surface of a micro-electromechanical system (MEMS) device formed on a substrate, and further comprising:

using the reflection to monitor movement of the moving surface.

[c29] 29. A device, comprising:

a disk spindle system to hold at least one optical storage disk which is operable to interact with light for optically writing or reading data; and

an optical fiber positioned relative to said spindle system with an optical core substantially parallel to the disk to couple said light to and from the disk, said fiber having a first distal end and a second distal end, wherein said second distal end includes an end facet that is at least partially reflective and forms an angle of about 45 degrees with respect to said fiber core to reflect said light in a direction substantially perpendicular to said fiber core onto the disk and to direct reflected light from the disk into said fiber core.

[c30] 30. The device as in claim 29, further comprising at least another fiber similarly constructed as said fiber and positioned parallel to the disk to interact with a location on the disk different from a location interacted with said fiber.

[c31] 31. The device as in claim 30, wherein said fiber and said at least another fiber are coupled to a same laser and a same photodetector.

[c32] 32. The device as in claim 29, wherein said disk spindle system is operable to hold at least another optical disk in parallel to the disk, and the device further comprising at least another fiber similarly constructed as said fiber and positioned parallel to the another disk to couple another light for writing or reading data.

[c33] 33. The device as in claim 32, wherein said fiber and said at least another fiber are coupled to the same laser and the same photodetector.

[c34] 34. The device as in claim 29, where said fiber distal end facet has a non-flat surface profile.

[c35] 35. The device as in claim 29, where said fiber distal end facet is coated with one or more layers of one or more light-reflecting materials.

[c36] 36. A method, comprising:

directing a light beam along a fiber to a distal end of the fiber;

using an end facet at the distal end to reflect the light beam out of the fiber in a direction substantially perpendicular to the fiber; and

directing the light beam to an optical disk, whose surface is substantially parallel to the fiber, to read or write data.

[c37] 37. The method as in claim 36, further comprising using one or more other fibers with reflective end facets to direct other light beams to different locations on the optical disk to read or write data at the same time.

[c38] 38. The method as in claim 36, further comprising using one or more other fibers with reflective end facets to direct one or more other light beams to different locations on the optical disk to produce reference signals to align the fiber that is reading and writing the data.

[c39] 39. The method as in claim 36, further comprising using one or more other fibers with reflective end facets to direct one or more other light beams to one or more other disks to read or write data, the said other disks engaged to the same spindle as said optical disk.

Rule 1.126

[c40] 40 ~~41~~. The fiber device as in claim 36, where said fiber distal end facet is polished or formed to include multiple-planes for light reflection.

[c41] 41 ~~42~~. The fiber device as in claim 36, where said fiber distal end facet is polished or formed to include curved surfaces for light reflection.

[c42] 42 ~~43~~. The fiber device as in claim 36, where said fiber distal end facet is coated with one or more layers of one or more light-reflecting materials.

[c43] 43 ~~44~~. The method as in claim 36, further comprising directing said light beam encompassing multiple wavelengths of light through said fiber onto multiple layers of data on said optical disk in order to read or write said multiple layers of data.

[c44] 44 ~~45~~. A device, comprising:

a fiber bundle having a plurality of optical fibers whose first distal fiber ends are in a common plane, each of said first distal fiber ends including an end facet that is at least partially reflective and forms an angle with respect to a fiber core of each fiber to reflect an optical beam into or out of said fiber core along a line that passes through a common point; and

a single fiber having a coupling distal end with an angled and reflective end facet and positioned to place said coupling distal end at said common point to optically communicate with each of said first distal fiber ends in said fiber bundle by reflection of said end facet when said single fiber is rotated at each of different orientations.

[c45] ~~46~~ 45. The device as in claim ~~45~~ 44, wherein said single fiber is coupled to receive an input beam and to couple said input beam to a selected fiber in said fiber bundle in response to a control signal.

[c46] ~~47~~ 46. The device as in claim ~~45~~ 44, wherein said single fiber rotates to a selected orientation to receive a beam from a selected fiber in said fiber bundle in response to a control signal.

[c47] ~~48~~ 47. The device as in claim ~~45~~ 44, further comprising a rotator to change a relative orientation of said single fiber with respect to said fiber bundle, and a control circuit coupled to control an operation of said rotator to change said orientation.

[c48] ~~49~~ 48. The device as in claim ~~45~~ 44, wherein said angle in each fiber in said fiber bundle is about 45 degrees.

[c49] ~~50~~ 49. The device as in claim ~~45~~ 44, wherein said angle in each fiber in said fiber bundle is an oblique angle.

[c50] ~~51~~ 50. The device as in claim ~~45~~ 44, wherein said common point is out of said common plane.

[c51] ~~52~~ 51. The device as in claim ~~45~~ 44, wherein said common point is in said common plane.

[c52] ~~53~~ 52. The device as in claim ~~45~~ 44, where one or more of said fiber distal end facets are polished or formed to include multiple-planes for light reflection.

[c53] ~~54~~ 53. The device as in claim ~~45~~ 44, where one or more of said fiber distal end facets are polished or formed to include curved surfaces for light reflection.

[c54] 54 ~~55~~. The device as in claim 44 ~~45~~, where one or more of said fiber distal end facets are coated with one or more layers of one or more light-reflecting materials.

[c55] 55 ~~56~~. A device, comprising:

a single fiber having a coupling distal end with an angled end facet to reflect light into or out of its fiber core;

a plurality of optical fibers, with end facets formed perpendicular to the fiber axes, and arranged to have their first distal ends in a common plane or in a plurality of common planes; and

a fiber rotator coupled to rotate said single fiber around its fiber axis to allow said angled end facet to receive light from or send light to each of said first distal fiber ends at a different orientation.

[c56] 56 ~~57~~. The device as in claim 55 ~~56~~, wherein said plurality of optical fibers form a fiber bundle.

[c57] 57 ~~58~~. The device as in claim 55 ~~56~~, wherein a portion of each of said fibers close to each of said first distal ends is in said common plane, and said single fiber is substantially perpendicular to said common plane.

[c58] 58 ~~59~~. The device as in claim 55 ~~56~~, wherein said angled end facet of said single fiber incorporates a diffraction grating for the purpose of spatially separating different wavelengths of light exiting or entering the fiber.

[c59] 59 ~~60~~. The device as in claim 55 ~~56~~, wherein said plurality of optical fibers form more than one fiber bundle in more than one common plane in order to receive more than one beam of spatially separated light from said single fiber.

[c60] 60 ~~61~~. A method, comprising:

directing a light beam into or out of a single fiber from a distal end that has a reflective facet forming an angle with respect to the fiber core; and

rotating the single fiber to rotate the reflective facet to receive said light beam from or direct said light beam to distal ends of a plurality of other fibers, one at a time at a different orientation, the other fibers arranged to have the distal ends in a common plane.

[c61] 61 ~~62~~. The method as in claim 60 ~~61~~, wherein the other fibers form a fiber bundle and have angled facets at their distal ends.

[c62] 62 ~~63~~. The method as in claim 60 ~~61~~, wherein at least a portion of the other fibers close to the distal ends are in the common plane, and the reflective facet of the single fiber is in the common plane and is rotated around an axis perpendicular to the common plane.

[c63] 63 ~~64~~. A device, comprising:

a reference fiber having a first terminal and a second terminal;

a signal fiber having a first terminal and a second terminal, and a tapered section between said first and second terminals which has a reduced dimension to allow a desired portion of a guided optical beam at a signal frequency to exist outside said signal fiber in form of an evanescent field;

a first optical coupler to divide a signal laser beam at said signal frequency into a first signal beam and a second signal beam of an equal intensity and to couple said first and said second signal beams into said first terminals of said signal and said reference fibers, respectively;

a second optical coupler coupled to said second terminals of said signal and said reference fibers to combine said first and said second signal beams into an output

signal beam in which said first and said second signal beams are 180 degrees out of phase relative to each other;

a measurand surface disposed adjacent to said tapered section of said signal fiber to absorb optical energy in said evanescent field; and

a signal photodetector to receive said output signal beam from said second optical coupler to produce a detector output indicating a spacing between said measurand surface and said signal fiber at said tapered section.

[c64] 64 ~~65~~. The device as in claim 63 ~~64~~, further comprising a phase-lock element to maintain said first and said second signal beams are at a specific phase relative to each other at said second optical coupler.

[c65] 65 ~~66~~. The device as in claim 63 ~~64~~, wherein said phase-lock element is operable to change a phase delay in at least one of said signal and said reference fibers.

[c66] 66 ~~67~~. The device as in claim 63 ~~64~~, wherein said phase-lock element is operable to measure an interference between two reference signal beams respectively passing through said signal and said reference fibers at a reference frequency that is not absorbed by said measurand surface to determine a relative phase change in said reference and said signal fibers, wherein said interference is measured from an output reference beam produced by said second optical coupler.

[c67] 67 ~~68~~. The device as in claim 63 ~~64~~, further comprising a wavelength-selecting element to separate said output signal beam and said output reference beam, and a reference photodetector to receive said output reference beam.

[c68] 68 ~~69~~. The device as in claim 63 ~~64~~, further comprising more than one of said tapered sections on said signal fiber for the purpose of observing the motion of more than one of said measurand surfaces.

[c69] 69 ~~70~~. The device as in claim 68 ~~69~~, further comprising more than one of said measurand surfaces oscillating at substantially different frequencies for the purpose of separating, in frequency, said output signal beams for each of said measurand surfaces.

[c70] 70 ~~71~~. The device as in claim 68 ~~69~~, further comprising one or more actuators to modulate the position of one or more of said tapered sections for the purpose of shifting the frequencies of one or more of said output signal beams and separating, in frequency, said output signal beams for each of said measurand surfaces.

[c71] 71 ~~72~~. A method, comprising:

guiding a light beam to a distal end of a fiber;

reflecting the light beam out of the fiber by an end facet which forms an angle with respect to the fiber core so that the reflected beam is substantially perpendicular to the fiber core;

directing the reflected beam to a biological tissue surface to which the fiber is substantially parallel in order to use the light beam to modify the biological tissue.

[c72] 72 ~~73~~. The method as in claim 71 ~~72~~, where said fiber distal end facet has a non-flat surface profile.

[c73] 73 ~~74~~. The method as in claim 71 ~~72~~, wherein said light beam is used to ablate, cauterize, or coagulate said biological tissue.

[c74] 74 ~~75~~. The method as in claim 71 ~~72~~, wherein said biological tissue is human cancer cells.

[c75] 75 ~~76~~. The method as in claim 71 ~~72~~, wherein said biological tissue is arterial plaques.

[c76] 76 ~~77~~. A method, comprising:

guiding a light beam to a distal end of a fiber;

reflecting the light beam out of the fiber by an end facet which forms an angle with respect to the fiber core so that the reflected beam is substantially perpendicular to the fiber core;

directing the reflected beam to a biological tissue surface to which the fiber is substantially parallel.

receiving light scattered or reflected from the biological tissue back into the fiber by reflection off the end facet to make measurements of properties of the biological tissue.

[c77] 77 ~~78~~. The method as in claim 76 ~~77~~, wherein said light beam is a laser beam.

[c78] 78 ~~79~~. The method as in claim 76 ~~77~~, wherein said light beam is a low-coherent source of light.

[c79] 79 ~~80~~. The method as in claim 76 ~~77~~, where said fiber distal end facet has a non-flat surface profile to modify a beam.

[c80] 80 ~~81~~. The method as in claim 76 ~~77~~, wherein said fiber with said end facet is used as a probe tip for an optical coherence tomography device.

[c81] 81 ~~82~~. A device, comprising:

a single fiber having a coupling distal end with an angled end facet to reflect light into or out of its fiber core;

a plurality of optical fibers arranged to have their first distal ends to couple optical signals to said coupling distal end through propagation in free space; and

a fiber rotator coupled to rotate said single fiber around its fiber axis to allow said angled end facet to receive light from or send light to each of said first distal fiber

ends at a different orientation.

[c82] 82 ~~83~~. The device as in claim 80 ~~81~~, wherein said single fiber is configured to have a sufficient dispersion to separate different optical signals of different wavelengths in a WDM signal and direct said different optical signals to different fibers among said fibers, respectively.

[c83] 83 ~~84~~. The device as in claim 82 ~~83~~, further comprising a diffraction grating formed on said angled end facet of said single fiber.

Figures